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Original Article

Changes in physical performance across the season in professional soccer players: A comprehensive evaluation of aerobic capacity, jump performance, and anthropometric characteristics

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Abstract
Problem statement and purpose: Soccer, involves high-intensity bouts and unpredictable demands, requiring a thorough understanding of the sport's physical requirements for to optimize training strategies. Professional players cover substantial distances during matches, frequently shifting between different intensity levels. While most actions are of lower intensity, high-intensity efforts, such as sprints and rapid changes of direction, play a critical role in performance. **Approach**: Comprehensive evaluations, including the Countermovement Jump (CMJ) and Mognoni Test, are critical to capture physiological results and ensure high-level performance throughout the season. A cohort of 28 male professional soccer players from a Serie C team underwent assessments at three points during the season. Tests included anthropometric measurements, the Mognoni field test for aerobic capacity, CMJ for explosive strength, and a High Intensity Running Test (HIT). All tests were conducted under standardized conditions, and statistical analyses employed ANOVA or Krustal-Wallis tests.
Results: Body fat percentage significantly decreased across evaluations, indicating a positive adaptation. Blood lactate concentrations in both Mognoni and HIT tests decreased, suggesting improved aerobic capacity and adaptation to high-intensity training. CMJ parameters remained stable, except for a decrease in CMJ normalized power. Individual variability in vertical jump performance emphasizes the need for continual neuromuscular stimulation. The results showed dynamic physiological adaptations during the soccer season. **Conclusion:** Our study suggests that optimizing body composition, monitoring training loads, and addressing individual responses are crucial for effective training. Coaches should prioritize monitoring power normalized per weight and blood lactate during the competitive season to tailor interventions for maximal efficiency in explosive movements and overall performance.
Keywords: Soccer, Seasonal Adaptations, High-intensity, VO_2max, Explosive Strength

Introduction

Soccer consists of high-intensity bouts with periods of low-intensity physical demands which results in a complex and challenging physical effort (Bangsbo et al., 2007; Vanlommel et al., 2013) The modern game emphasizes not only endurance but also explosive power, requiring players to perform high-intensity efforts interspersed with periods of lower-intensity activity(Bongiovanni et al., 2021; Wing et al., 2020). These fluctuations demand optimal aerobic capacity to support recovery and sustain performance throughout the 90 minutes of a match (Bangsbo et al., 2006).

Understanding the physical requirements during a soccer match, become crucial for an appropriate training planning. Indeed, professional soccer players typically cover a distance ranging between 10 to 13 km throughout a match, involving approximately 1400 changes in activity that occurred every 4 seconds (Taylor et al., 2017). While many of these actions involve low metabolic demand, high-intensity efforts, such as high-intensity runs (> 19.8 km/h that represent the 8% of the total distance covered), sprints (40 to 60 for a total of 0.3 to 0.6 km), sudden changes of direction (cuts), and rapid deceleration (Bastida Castillo et al., 2018; Taylor et al., 2017; Wallace & Norton, 2014). Explosive actions, such as jumps and accelerations, are particularly important in pivotal moments, like goal attempts or defensive plays, emphasizing the need for both aerobic endurance and lower limb power (Haller et al., 2022; Lupowitz, 2023). The ability to recover quickly between these efforts is crucial, especially in professional leagues where the intensity of competition increases during the season (Bangsbo et al., 2006).

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Despite the extensive research on the physical demands of soccer, there remains a gap in understanding the seasonal adaptations of professional players, particularly in relation to aerobic capacity, explosive strength, and body composition. While some studies have focused on individual aspects of performance, there is limited comprehensive analysis that tracks these variables simultaneously across the season. Given the demanding nature of the sport and the varying physical loads experienced by players, monitoring these changes is crucial for optimising training strategies and minimising injury risk(Hostrup & Bangsbo, 2023).

Specifically, the focus of trainers primarily is to evaluate players's performance throughout the season to intercept any decrease (Los Arcos et al., 2017). Silva et al. (Silva et al., 2016) confirmed that monitoring the performance at different moments of the season should be crucial to keep high performance of the players considering, also, that anthropometric characteristics remain relatively stable during the season (Silva, 2022). Specifically, body mass does not change, absolute and relative body fat decreases, whereas lean body mass tends to substantially increase from preseason to beginning, with no substantial decreases within in-season assessments. Further, variations in body composition appear to be independent of players' time participation time or position-role. Analyzing performance, Silva (Silva, 2022) about CMJ showed improvement with small to moderate effect sizes from preseason to the beginning competition season, middle season, and end of season while linear speed moderately decreased during the off-season: both for acceleration phase (~2.5%) and maximal velocity phase (~7%). Change of Direction speed is negatively affected during the off-season but tends to improve during preseason training (e.g., 4 × 10 m) while remaining unchanged in more complex task (e.g., T-test, (Sporis et al., 2010). Contradictory findings were observed in different assessments from pre to mid-competitive phase of the season. It remains crucial for trainers to evaluate how the performance of soccer players changes during the season. Considering these, the competitive nature of Serie C and similar leagues exerts considerable pressure on players to maintain high levels of physical fitness throughout the season (Izzo et al., 2022). With over 40 matches played during the competitive calendar and frequent high-intensity training sessions, it is of paramount importance to comprehend how players adapt to the physiological stress. As fatigue accumulates and body composition changes, the capacity to monitor and adjust training loads becomes crucial for the prevention of injury and the enhancement of performance.

The objective of this study was to evaluate changes in aerobic capacity, lower limb explosive strength, and anthropometric characteristics at three distinct time points during the season in a professional soccer team. By integrating these performance measures, we sought to gain a more nuanced understanding of the physical demands placed on professional soccer players over time and to provide coaches with actionable insights for optimising player performance through tailored training interventions.

Material & Methods

Participants

A total of 28 male professional soccer players (aged between 19 to 34 years) were recruited in 2021-2022 from a single Italian professional soccer team militant in the "Serie C" championship. After hearing the explanation of the study protocol, soccer players gave written informed consent. Any player was free to withdraw from the evaluation at any time without consequences. This study was approved by the manager of the team in accordance with the chief of the medical staff (Internal communication CR-4.7.21). All procedure were conducted in accordance with the Declaration of Helsinki (World Medical Association, 2013).

Procedures

To evaluate players' performance across the season, three sessions of tests have been programmed at different moments of the season. The first session (T0) was taken before the beginning of the championship, on the first day of the summer pre-season gathering (second week of July) after the detraining due to the annual pause. The second (T1) was taken in autumn in correspondence of the halfway through the first half of the season,(second week of November; after 10 matches played and 78 sessions of training). The third assessment (T2) were in spring, halfway through the second half of the season (after 40 matches and 183 sessions of training). All session were carried out following the same procedure and timing. The first assessments were at 9.00 am for anthropometric measurement (weight, height and skinfolds). After (avoiding warm-up phase) the players started the second assessment about the aerobic capacity. After 30 minutes of rest, the third test were administrated with a series of CMJ whereas some pre-jumps were used as a warm-up. At the end (after 15 minutes) a high intensity running test was executed. The protocol of testing for each player takes around 1 hours. The day before the session all players did not participate to the training.

Anthropometric characteristics

Standing height was measured with a stadiometer (Seca 213, Seca GmbH & Co., Hamburg, Germany) to the closest 1 cm, with students standing upright and with their heads in the Frankfurt plane. Body mass was evaluated using a balance scale (Seca 864, Seca GmbH & Co., Hamburg, Germany) to the nearest 0.1 kg. These anthropometric characteristics were assessed following the guidelines provided by the International Society for the Advancement of Kinanthropometry (da Silva & Vieira, 2020). BMI was calculated using standing height and weight data: body mass (Kg) divided by squared height (m^2).

To estimate body fat, three skin folds (using the Skinfold Caliper, HSB-BI Harpenden) at three different points (pectoral, abdominal, and thigh) as well as the circumferences of biceps and waist were assessed and used within the Jackson and Pollock equation validated for professional soccer players (Sinning et al., 1985).
All the anthropometric characteristics were measured at the beginning of every session, at roughly the same time (9-9:30 am), with the same instruments and in the same location (infirmary) were a constant temperature (20-21^{o} C) were preserved.

Aerobic capacity

To assess aerobic capacity, the Mognoni field test (Sassi et al., 2006) was carried-out. This test was specifically validated for soccer players and, measuring blood lactate level, is possible to identify the anaerobic threshold speed and evaluate aerobic capacity. Players must run following an elliptical path of 300 m on for 6 minutes, keeping a pace of 13.5 km/h with an audible signal every 50 m: the total distance covered in the 6 minutes then was 1350 m. Next, a micro-sample of capillary blood was taken from the earlobe and immediately analysed with a lactate meter (Lactate Plus® - Nova Biomedical) to measure blood lactate concentrations (mmol/l). End-of-test Heart Rate (using a Polar FT1® heart rate monitor) and perception of fatigue (using Borg's 0-10 scale) were also collected (Pfeiffer et al., 2002).

Lower limb power

CMJ was used to assess lower limb explosive strength. Players, starting in standing position with the hands on the hips, must jump vertically as high as possible after a squat (counter movement) reaching the knees flexion of ~90°, while keeping the trunk straight. Jump height has been measured with an accelerometer put on a belt around players' waist (Myotest accelerometric system®, Myotest SA, Sion Switzerland), already used in other studies (Casartelli et al., 2010). Jump height, force, peak power output (including power/force-body mass ratio) were automatically computed by the software.

High Intensity Running Test (HIT)

The HIT protocol consisted of 10 sets of 10-second shuttle runs over a 25+25-meter course, involving a 180° change of direction and 20 seconds of recovery between each bout (Rampinini et al., 2010). Players were instructed to run at 18 km/h, following a sequence of audio cadence. Immediately after the HIT protocol, a 100 µL capillary blood sample was collected into a heparinized capillary tube and analyzed for blood hydrogenion concentration ([H+]) and bicarbonate concentration ([HCO3-]) using a calibrated blood gas analyzer (GEM Premier 3000, Instrumentation Laboratory, Milan, Italy) with an Intelligent Quality Management System cartridge. Additionally, capillary blood sample (5 µL) were analyzed for [La-] using a portable microvolume lactate analyzer (Lactate Plus, Nova Biomedical, Waltham, MA, USA). Fatigue perception at the end of the test, assessed using Borg's 0-10 scale (Pfeiffer et al., 2002), was collected. All players were familiar with and accustomed to using this scale, eliminating the need for familiarization in the study.

Statistical Analysis

All quantitative data were summarised as mean and standard deviation (SD). The normality was verified by Shapiro–Wilk test and by a graphical output. To compare the performance between the three different assessment sessions One-Way ANOVA with Bonferroni correction or an ANOVA of Krustal-Wallis were applied respectively for normal or non-normal distribution. All the significance was set at a p-value less than 0.05. Statistical analyses were performed using "The Jamovi project (2021)" within Jamovi Version 1.6 for Mac [Computer Software], Sydney, Australia; retrieved from https://www.jamovi.org (accessed on 5 Oct 2023).

Results

The descriptive characteristics of the total sample are presented in Table 1.

Table I. Descriptive characteristics of the total sample.
Abbreviation. Blood La= Blood lactate

		T0	T1	T2
Anthropometrics	*Body fat (%)*	9.83 ± 2.29	8.52 ± 1.72	7.47 ± 1.81
Mognoni	*Blood La*	4.68 ± 1.95	3.65 ± 1.80	3.07 ± 0.92
	RPE	4.71 ± 1.27	4.13 ± 1.41	3.44 ± 1.17
HIT	*Blood La*	6.87 ± 2.08	3.94 ± 1.17	3.71 ± 1.08
	RPE	6.92 ± 1.19	4.63 ± 0.77	4.72 ± 1.81

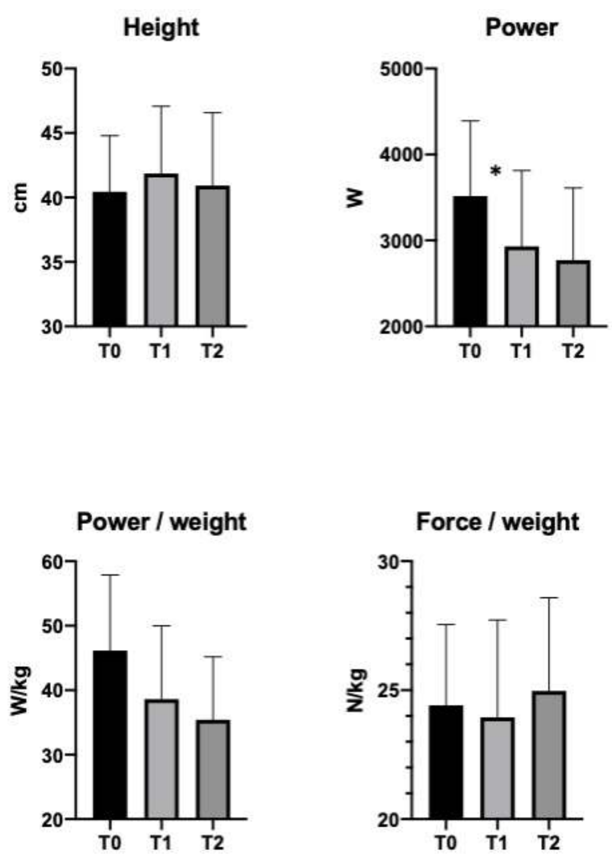
Only 17 soccer players completed all the testing sessions. As reported in Table 2, body fat percentage decreased between the different evaluations (p <0.001). Post hoc analysis revealed that the comparison between T0 and T1 (p-< 0.001) and between T1 and T2 (p = 0.02) were significant.

Table II. Comparison of body fat percentage, Mognoni and HIT test performance of soccer players during the season (Mean ± Standard Deviation).
Abbreviation. Blood La= Blood lactate

	Anthropometrics	Mognoni		HIT	
	Body fat (%)	*Blood La*	*RPE*	*Blood La*	*RPE*
T0	9.83 ± 2.29	4.68 ± 1.95	4.71 ± 1.27	6.87 ± 2.08	6.92 ± 1.19
T1	8.52 ± 1.72	3.65 ± 1.80	4.13 ± 1.41	3.94 ± 1.17	4.63 ± 0.77
T2	7.47 ± 1.81	3.07 ± 0.92	3.44 ± 1.17	3.71 ± 1.08	4.72 ± 1.81

The blood lactate concentrations for the Mognoni test did not follow a constant trend during the season (p-value < 0.001). Specifically, the blood lactate concentrations decreased between T0 and T1 (p < 0.001) while remained stable between T1 and T2 (p > 0.05). The RPE mean values showed no decrease between T0 e T1 (p > 0.05) and between T1 e T2 (p > 0.05) even if the comparison T0-T2 revealed a difference (p = 0.019).
The blood lactate and RPE collected during HIT test decreased in soccer players (p < 0.001). Despite this, both the blood lactate and the RPE remained stable between T1 and T2 (p > 0.05) while they decreased between T0 and T1 (p < 0.001).
Our analysis showed that during the season the CMJ height, power and explosive strength did not change (p > 0.05), while the CMJ normalized power decreased (p = 0.022), specifically between T0 and T1 (p = 0.025).

Figure I. Countermovement Jump parameters trend across the season of professional soccer players.
*p< 0.05



Discussion

Our analysis of the seasonal changes in physical performance indicators among soccer players reveals significant fluctuations in body composition, physical stress markers, and specific parameters of jumping performance, shedding light on the dynamic nature of their physiological adaptations during the course of a competitive season (Silva, 2022). Specifically, our results confirmed only partially these trends. Indeed, body fat decreased significantly across evaluation session; further, blood lactate in HIT and Mognoni test decreased significantly. All collection of RPE showed a decrease of mean value indicating an improvement in effort endure. CMJ parameters remained stable, but CMJ normalized power decreased between sessions.

Our results suggested a decrease in body fat through the session of the test, from preseason to the end of the season, in accord with the literature (Meckel et al., 2018). The significant decrease in body fat percentage among the evaluations is a relevant aspect because it links body composition to athletic performance. Indeed, excessive body fat imposes additional stress and load on players during performance while increased lean body mass (muscle mass) facilitates neuromuscular function, which plays a crucial role in high-impulse actions like sprints, jumps and duels (Owen et al., 2018). Furthermore, players with higher chronic competition exposure tend to exhibit higher performance in muscle power actions, suggesting that match exposure serves as an important stimulus during a training session. Considering that the lactate is considered as a valid marker for aerobic capacity that can reflect the training status (Edwards et al., 2003; Faude et al., 2009) our results showed a decrease in blood lactate during HIT, probably reflecting an adaptation to the high intensity training. There is also a clear indication that the time spent on high training intensities during physical preparation (pre-season) is a valid indicator for training monitoring. However, the results of this research about vertical jump performance, suggests a stability over time (CMJ height, CMJ power), as it suggests that not all performance variables were affected during the season. In general, this is not far removed from the literature that suggests that variations in CMJ illustrate considerable variability in athletes' responses, suggesting the need for coaches to provide constant stimulation throughout the entire season (Meckel et al., 2018; Silva, 2022). Further, Köklü et al (Köklü et al., 2015) and Wisløff et al (Wisløff et al., 2004) showed a positive correlation between sprint and vertical jump in soccer probably due to the common muscle power request. Indeed, recently, Requena et al. (Requena et al., 2017) showed that jump performance can improve during the pre-season and the season, it is important to consider individual differences in responses to training and matches. In a review, Silva (Silva, 2022) noted that the ability to maximize mechanical power and the ability to withstand fatigue during the repetition of the CMJ improve with moderate magnitude during pre-season compared to the middle of the competitive period and with reduced magnitude during the end of the competitive period. But when our data associated CMJ/body mass, the performance decrease in power/Kg, especially between the first and the second session, suggesting a change in athletic performance that could have important implications on the physical abilities of athletes in the specific context of soccer. Accounting for this, the reduction of jump considering the body mass may indicate a decrease in the body's efficiency or ability to generate strength relative to body mass during the season. Wisløff et al, (2004) highlight the importance of jumping and the power of the lower limbs in soccer players. Physical adaptation and athletic condition can have a significant impact on athletic performance and, consequently, on the ability to generate strength relative to body mass. Efficiency in jumping is closely related to muscle strength and the ability to generate explosive power, essential factors in high-intensity athletic actions in professional soccer (Suchomel et al., 2016). The variation of vertical jump performance becomes a tale of individual variability, emphasizing the need for coaches to provide continual neuromuscular stimulation during years. This aligns with recent studies that highlight the varied responses of athletes, emphasizing the importance of tailoring training approaches (Giuriato & Lovecchio, 2018). Measurement of relative power, in this case through jumping tests, offers a direct indication of the athlete's ability to generate strength compared to body mass.

Conclusion

Our comprehensive examination of seasonal physiological and performance dynamics in soccer players not only offers a comprehensive representation of their adaptability but also establishes the foundation for a practical and personalised approach to training. It is evident that coaches stand to benefit from optimising body composition, closely monitoring training loads and integrating specific strategies to maximise efficiency in explosive movements. The findings of this study indicate that power normalised per weight and blood lactate (Mognoni and HIT) decline during the competitive season in soccer. This suggests that coaches should monitor these parameters during the season. Additionally, these findings indicate that coaches and athletic trainers should prioritize the control of body composition and training loads to maximize efficiency in explosive movements and optimize aerobic capacity. The practical contribution of this study is the recommendation to integrate strategies aimed at reducing fat mass and monitoring relative power on a consistent basis to prevent a decline in performance. Furthermore, the findings suggest that training load adaptation is crucial for sustaining high levels of performance during the competitive season, thereby reducing the risk of injury. It would be beneficial for future studies to explore individual variability in training responses in more detail, taking into account different roles on the pitch and playing time, in order to further improve physical preparation strategies in professional football.

Conflicts of interest
No conflicts of interest to declare.

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